The time evolution of GRB spectra by a precessing lighthouse Gamma Jet

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Inverse Compton Scattering (ICS) by a relativistic electron beam jet at GeV energies (emitted by a compact object as a NS, BH,...), a NSJ, onto thermal BBR photons (from a nearby stellar companion) may originate a collinear gamma jet (GJ). Due to the binary system interaction the GJ precession would blaze suddenly toward the observer leading to a GRB event. The internal GJ cone structure is ruled by relativistic kinematics into a concentric onion-like sequence of photon rings, the softer in the external boundaries, the harder in the inner cone. The pointing and the crossing of such different GJ photon rings to the detector lead to a GRB hardness spectra evolution nearly corresponding to most observed ones. Moreover expected time integral spectra are also comparable with known GRB spectra. The total energy input of tens of thousands of such NSJ in an extended galactic halo, mainly cosmic rays electrons, should be reflected into the recent observational evidence (COMPTEL) of a diffused relic extended halo. Evidences of such precessing jets are offered by the discover of galactic superluminal sources, recent HH jets, SN1987A outer rings, Hourglass Nebula, planetary Egg Nebula, GROJ1744-28 binary X-rays pulsar.

As in the previous paper we were forced to build up our GJ model by the ICS process made by relativistic cosmic rays electron jet onto BBR photons. To obtain an analytical "direct" formula we first studied the Compton Scattering of the anisotropic boosted "BBR" in the electron rest frame and then we transformed back in the laboratory frame the resulting ICS output. This approach has been successfully tested with the experimental ICS spectrum onto room thermal BBR photons performed at LEP [1-2]. However in our binary model the NSJ moves in presence of an inhomogeneous and anisotropic flux of photons coming from a nearby companion BBR star source. For sake of simplicity (without any loss of generality) we first assumed a ring-like photon source within a limited incident angle ($\theta_o \sim 45^o$) for the incoming photons. The luminous ring plays the role of the companion star, its radial distance from the jet, and integral intensity have the same behaviour and luminosity of a binary star source at the same radial distance. In the ultrarelativistic-

Thomson limit the ICS differential photon number distribution is [3]

$$\frac{dN_1}{dt_1 d\epsilon_1 d\Omega_1} = \frac{2\pi\kappa_B T r_o^2 c}{c^3 h^3} N_o \epsilon_1 \int_{\gamma_{min}}^{\gamma_{max}} \frac{\gamma^{-\alpha-2}}{\beta} \cdot$$

$$\cdot \ln\left[\frac{1-\exp\left(\frac{-\epsilon_1(1-\beta\cos\theta_1)}{\kappa_B T(1-\beta\cos\theta_{o,min})}\right)}{1-\exp\left(\frac{-\epsilon_1(1-\beta\cos\theta_1)}{\kappa_B T(1-\beta\cos\theta_{o,max})}\right)}\right] \cdot \left[1+\left(\frac{\cos\theta_1-\beta}{1-\beta\cos\theta_1}\right)^2\right] d\gamma \qquad (1)$$

where ϵ_1 is the observed final photon energy, N_o is a normalizing factor (consistent with the total flux intensity of GRBs $\dot{E}_\gamma \sim 5\cdot 10^{41}\ erg\ s^{-1}$ described in eq.4 of ref.[5]), $\theta_{o,min}$ and $\theta_{o,max}$ are the nominal incident angles between the jet beam direction and the thermal photons. In this formula θ_1 (the final external cone angle from the core) evolves with the GJ sweeping. Indeed the GJ hitting and crossing by the observer reflects in the simplest configuration (at small angle approximation) into an angle evolution $\theta_1(t) = \sqrt{\theta_{1,min}^2 + (\omega_b t)^2}$ where t=0 corresponds to the maximum of the GRB rate and $\theta_{1,min}$ is the observed minimal angle from the beam jet center toward the observer. Because of the sharp rate decrease at large angle in eq.1 (and eq.3), the approximation holds also at large angles $\gamma\theta_1(t) \gg 1$. Overimposed to this simplest angular variation one should expect a (nearly) periodic "trembling" at millisecond, the inprint of the pulsar jet at the characteristic ω_{PSR} frequency. Moreover an additional nutation of the spinning star is possible ($\omega_N \sim \omega_{PSR}\frac{I_\perp - I_\parallel}{I_\parallel}$) driving the final angle beam θ_1 to a fascinating dance along a multiple cycloidal (or epicycloidal) trajectory described by the angle $\theta_1(t)$ written as follows:

$$\theta_1(t) = \sqrt{[\theta_{1,min} + \theta_{PSR}\cos(\omega_{PSR}t + \varphi_{PSR}) + \theta_N\cos(\omega_N t + \varphi_N)]^2 + \overline{+[\omega_B t + \theta_{PSR}\sin(\omega_{PSR} + \varphi_{PSR}) + \theta_N \sin(\omega_N t + \varphi_N)]^2}} \qquad (2)$$

where ω_b, ω_{PSR}, ω_N are respectively the binary system, the characteristic pulsar, the nutation NSJ frequencies. The free constant parameters $\theta_{1,min}$, θ_{PSR}, θ_N are the minimal "impact" angle for θ_1, the maximal angular amplitude of the NSJ "trembling" and the corresponding maximal oscillation during the angular nutation; φ_{PSR} and φ_N are the constant phases defined by the characteristic initial conditions. The temporal spectral evolution of GRBs is given in detail by substituting the previous $\theta_1(t)$ behaviour in eq.1. The consequent adimensional total photon flux number time evolution, for a monochromatic electron jet spectrum, is (after integrating over ϵ_1 in eq.1)

$$\frac{(dN_1/dt_1 d\Omega_1)_{\theta_1(t)}}{(dN_1/dt_1 d\Omega_1)_{\theta_1=0}} = \frac{1+\gamma^4\theta_1^4(t)}{[1+\gamma^2\theta_1^2(t)]^4} \qquad (3)$$

The presence of 8 parameters $\theta_{1,min}$, θ_{PSR}, θ_N, φ_{PSR}, φ_N, ω_b, ω_{PSR}, ω_N allows to fit the many different GRB faces and behaviours [6] as well as to

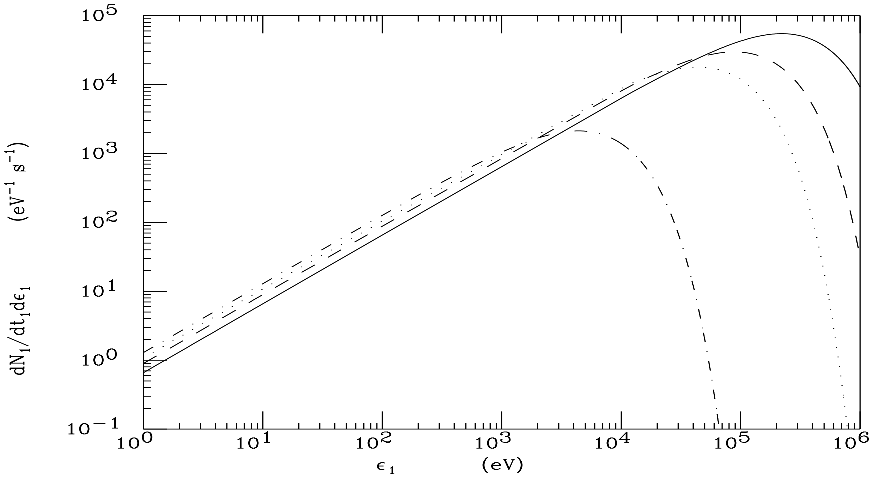

FIG. 1. ICS energy spectrum, in arbitrary units, for $\theta_1 = n/\gamma$ and n=1,2,3,10 angle apertures (from continuous to dot dashed curve)

understand the limiting case: if $\theta_{1,min}$ is large (and so more easely seen the jet because of the larger angle area) the average GRB energy is softer (SGR event) and less intense. The SGR repetition arises because, in eq.2, $\omega_b t$ (for GRB) is the limit function of a more general periodic one (for SGR): $\omega_b t \leftrightarrow \sin(\omega_b t)$. Moreover the peculiar case of a gamma ray pulsar is recovered from the same expressions when all the binary and nutation variability vanish ($\theta_N = 0$, $\omega_b = 0$) and only the pulsar trembling behaviour survives. If, for istance, we parametrize the θ_1 angle aperture in eq.2 in Lorentz factor unities, as $\theta_1 = \sqrt{\theta_{1,min}^2 + (n/\gamma)^2}$, then the GJ sweeping induces a violent "thermal" evolution soft-hard-soft (from eq.1) as shown in fig.1 where tens KeV and hundred KeV "thermal" spectra arise for angle evolution at n=1,2,3,10.

For most general $\theta_1(t)$ evolution (eq.2) the spectral behaviour is either rapid and trembling (within each GRB spike due to ω_{PSR}) as observed and also contains slow thermal evolution and repetition within lower epicycloidal frequencies (ω_b, ω_N). The final time integral for different $\theta_{1,min}$ angle in unidimensional "slices" of these "onion cones" number rate distribution in the usual form $F_\nu \nu = \epsilon_1^2 \frac{dN_1}{dt_1 d\epsilon_1}$ (from eq.1) are shown in fig.2.

The final integral over a power law electron spectrum fits in a successfully way the GRB experimental spectra. For a chaotic "random walk" around $\theta_{1,min}$ one may easely approximate the final spectrum by a total surface angular integral over θ_1 (see ref.[3] and the successfull fit of GRB910601_69736). The $\gamma - \gamma$ electron pair production opacity near the jet for the parameters given in ref.[3] is within unity and cannot lead to thermalization. The isotropy "obsession" of GRB which seemed to push all (or most) the theoreticians to-

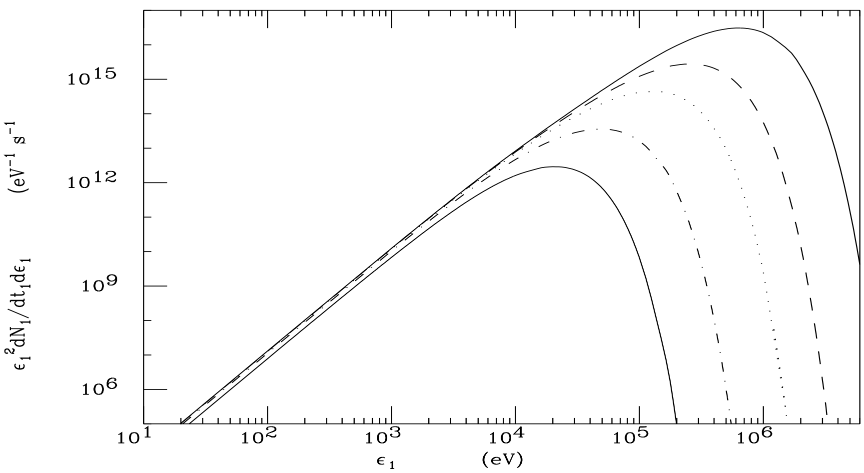

FIG. 2. ICS integral energy flux, in arbitrary units, for $\theta_{1,min} = n/\gamma$ and n=1,2,3,5,8 angle apertures (from upper continuous to lower continuous curve)

ward the popular cosmological belief cannot force the present GJ model toward those huge distances and energies. Indeed an amplification (by nearly 10 order of magnitude) of the GJ power ($\dot{E}_\gamma$) by a corresponding NSJ $\dot{E}_j$ power do *increase by the same factor the density of the electrons* in the jet (even disregarding the copious $e^+ - e^-$ pair production), leading to a total screening and opacity (like in fireball models) of the GJ and to a final *thermal GRB spectrum* (in disagreement with observations). Therefore cosmological GJ "versions" are not acceptable GRB sources. The total number N_T of such active GJ in an extended galactic halo may be roughly estimated by two main arguments: (a) the ratio between the jet lifetime (assuming a companion solar mass $M_\odot$ feeding by mass transfer the power jet) $\tau \sim \frac{E_{SN}}{\dot{E}_j} \sim 3 \cdot 10^7 yr$ and the birth time of such system (comparable to SN one) $\Delta\tau_{SN} \sim 30 yr$; (b) the ratio between the GRB observational probability and the GJ beam solid angle size. These GJ numbers are at first approximation respectively one million and 30000; a corresponding source density quite rare in an extended galactic halo. Since the end of 1993 we were inspired by the above arguments and by just two known galactic jet candidates: SS433 and the Great Annihilator IE1740.7-2942. In the last three years the candidates and the evidences for precessing GJ have blown up. The superluminal sources GRS1758-258, GRS1915+105 and GROJ1655-40 whose GJ nature and SGR association has been promptly noted [3]. The jet traces in HH34 filaments as in earlier notes [3] became evident by last deep Hubble inspections of their jet cores (HH30, HH1, HH2, HH34, HH47). Known SGRs have been identified as runaway *binaries* from their SNR birthplace with bright infrared companion (somehow obscured by

dust). The last discover of binary pulsar GROJ1744-28, discussed in ref.[5], is an ideal candidate for such precessing GJ. The evidence of high velocity NS (HVNS) may explain the isotropization and the diffusion into extended galactic halos of the GRB sources, consistent with observed isotropy. The GRB flux count break at lowest fluxes may be reflected into the coexistence of a bounded (homogeneous $\rho \sim cost$) extended halo (or corona <100 Kpc) and of an evaporating component ($\rho \sim 1/r^2 > 100$ Kpc). Last evidences of the twin rings around SN1987A are also favouring the presence of two sided precessing jet spraying onto the red giant relic shell. One may foresee [4] the presence of a NS relic moving from the SN core toward $\underline{South - East}$ (due to offaxis beaming and "rowing" acceleration processes). The final discovery (16 January 96) by Hubble of the Egg Nebula CRL2688 is probably the most spectacular and detailed view of such precessing GJ in space: the outer gas-dust (nearly homogeneous) spherical shells allow to diffuse and clearly put in evidence the symmetric sweeping of a (twin) conical shape of the precessing GJ in a "frozen" bright, convincing picture. GRBs are just similar sources located in extended galactic halo sweeping and trembling once the GJ beam cone points toward the terrestrian detectors.

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